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Predicting Total Costs: Should We Focus on Comorbidity Rather Than Individual Diseases?

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Abstract

Background: The objectives of this study were to determine the costs of care of a large cohort of primary care patients, and to develop models that identify the demographic and clinical features predictive of the total costs that patients incur over a one-year period.

Methods: The study involved a retrospective analysis of prospectively obtained clinical data on 15,186 patients who were seen at least once during a one-year period beginning December 1, 1993 in a general internal medicine faculty and resident practice in an urban academic medical center. Demographic and clinical data including diagnostic, medication, and resource utilization data were obtained from a computer system that was employed to manage patients in the practice. Hospital cost data was obtained from the hospital cost accounting system.

Results: The average cost per year for our 15,186 patients was $1,934 with a standard deviation of $7,257. As expected, hospital costs, which were $1,204, accounted for the largest proportion --- 62.3% -- of the total cost. Older patients, those with Medicare or Medicaid, had higher yearly costs. Patients with higher comorbidity had significantly higher costs, with steep increases in yearly costs for patients with comorbidity scores of two or more. Among individual comorbid diseases, patients with skin ulcers/cellulitis, and diabetes had the highest adjusted yearly costs (P<0001). Patients who were taking warfarin had especially increased costs (P<.0001).

Conclusions: Management of total costs may require attention to management of comorbidity and certain medications as well as specific diseases.

Key Words: Capitation, Cohort Studies, Costs and Cost Analysis, Cost of Illness, Risk Adjustment

Introduction

Predicting health care cost requires identifying those factors (disease entities, sociodemographic characteristics etc.) that drive costs longitudinally. This information can then be used to develop programs to control costs or adjust for costs.

Medicare and managed care organizations have used such prognostic models to set risk-adjusted capitation rates.[1,2] Medicare's adjusted annual per capita cost (AAPCC) method is currently based on sociodemographic characteristics such as age, gender, residence and whether a patient is institutionalized or disabled.[3] The AAPCC contains no clinical information, explains only a small amount of variation in health care costs. Because of its failure to adjust for clinical status, has led to overpayment for medical services for healthy older adults, enrollment strategies targeted to enroll the healthy and dissuade the chronically ill, and has had an adverse impact on vulnerable populations.[2,3,4]

As a result, Congress has mandated that by the year 2000, the Health Care Financing Administration link capitation payments to the clinical status of Medicare beneficiaries.[3,4] The problem is that, even as other models[2,3,5,6,7,8,9] have revisited and expanded on the AAPCC methodology, they still explain no more than approximately 13 percent of variation in costs. It is of note that comorbidity has not been formally incorporated as a predictor in these models, despite its proven ability in predicting mortality and its recognized importance in determining hospital costs.[10, 11]

The goal of this study was to determine the predictors of the total cost of care of a large cohort of primary care patients. We used computerized electronic medical records to construct a model that identifies the demographic and clinical features (including specific chronic illness syndromes, comorbidity and medications) predictive of the total yearly cost that patients incur over a one-year period in an academic general internal medicine practice.

METHODS

Population

This study included all 15,158 patients seen at the Cornell Internal Medicine practice during a one-year period beginning December 1, 1993. During this year, 7,716 patients were seen by 18 attendings. These attendings also supervised 153 residents who saw 7,470 patients during continuity and ambulatory block experiences.

Data Collection

The data for this paper was captured by CLIMACS ©, a computer system developed by one of the authors (JPH). All physicians used this system in the everyday care of patients to code outpatient diagnoses, to write all prescriptions and order laboratory tests, radiology tests, procedures and consultations. Therefore, CLIMACS© provided a prospectively collected database of demographics, appointments, ICD-9 diagnoses, medications, and resource utilization.

Demographic data were documented by the secretarial staff. Diagnoses were coded by physicians at the conclusion of each visit for billing purposes and thus were similar to administrative data; however, the list of diagnoses was cumulative. The Charlson comorbidity score [10] was employed to assess the prognostic burden of comorbid disease; the Deyo adaptation for ICD-9 data was used.[12] We then analyzed the database compiled during the one-year period starting December 1, 1993, and examined the subset of patients who had at least one physician visit during the one-year period.

As described elsewhere, in order to estimate for errors of undercoding, we compared data from CLIMACS with a chart review of the paper medical records regarding the diagnoses for diabetes mellitus, asthma and chronic obstructive pulmonary disease. For diabetes, the undercoding rates was 1.8% and for asthma/COPD, the rate was 7.7%.[13]

Resource utilization

All tests were ordered using CLIMACS, allowing assessment of resource utilization including the number of ambulatory visits, laboratory tests, radiology tests, specialty consultations, and other miscellaneous services such as vaccinations or procedures. Data on ambulatory resource utilization was converted from charges to cost using the specific ratio of cost-to-charges for each category of service. Inpatient costs were obtained from the hospital cost accounting system (Transition Systems Inc, Boston Mass). The vast majority of inpatient costs are captured by the system as actual costs, while a small minority are costs converted from charges by specific cost-to-charge ratios. The total cost includes the cost of ambulatory visits, laboratory tests, radiographic, consultations, as well as all costs generated during any hospitalizations.

The total costs did not capture all of care provided by external providers, including hospitalization at other hospitals and tests ordered by other providers and performed in outside laboratories. Similarly, hospital costs include only those costs at New York Hospital; if patients were hospitalized elsewhere, the costs were not captured. In order to assess the undercoding rate, we contacted a 1% random sample of patients. The rate of hospitalization at other facilities during the relevant time frame was 6.3% among the 158 patients who were interviewed by telephone.

Data analysis

For the univariate analysis of the relation of patients' demographic and clinical status to resource utilization, simple linear regression performed through GLM SAS[6] was used to screen each candidate predictor variable. Because the distribution of total costs was positively skewed, all analyses were carried out on the logarithm of the specific cost. However, to aid interpretation, descriptive statistics are presented as total costs. The univariate analyses were used to identify potential predictors to be incorporated in multivariate models. Since the initial evaluation involved more than 250 potential predictors, the value for univariate significance was set at .0001.

After univariate screening, the multivariate models were derived in a randomly selected 50% sample and tested in a validation 50% sample; each had 7,953 patients using PROC PLAN.[14] To be included in the final derivation model, in addition to achieving a significance level of .0001, the variables had to explain at least 1% of the variance in total cost. Explained variance was always calculated on the logarithm of the total costs. This approach uses both statistical significance and the strength of association in screening potential predictors.[15]

The initial validation model incorporated only those variables that were significant at the .0001 level in the derivation model. The final model contains only those variables that maintained significance at <.0001 in the validation model. The explained variance is reported for each model. Least square means were used to calculate adjusted values using GLM in the validation model.[16]

Results

1. Average yearly cost per patient

The average cost per year was $1,934. As expected, hospital costs, which were $1,204, accounted 62.3% of the total cost. Ambulatory costs including primary physician visits, consultations, laboratory tests, radiographic procedures and other tests totaled $730 per year and accounted for 37.7% of total costs. In total, 1,434 patients or 9.4 % of the patients were hospitalized an average of 1.4 times during the year. The total hospitalization cost for the patients who were hospitalized was $12,752, while their ambulatory costs were $1,095. Thus, yearly total cost for patients who were hospitalized was $13,847 with 91% attributable to the hospitalizations, and 9% to ambulatory costs. The cost per admission was $9,335.

2. Demographic and clinical predictors of total cost

The average age was 51, and more than two-thirds were women. Eighteen percent had Medicare; 27%, Medicaid; and 20%, managed care. While 86% had a comorbidity score of one or less; 7.5% a score of 2; and 6.2% a score of 3 or more.

Table 1 shows the average costs according to age, gender, insurance, and comorbidity. Among these variables, comorbidity explains the greatest variance in total cost –15.6%, while age accounted for 7.5% of the variance. Figure 1 shows that total yearly costs increase with older age and a greater burden of comorbidity, and they are especially high among patients with comorbidity scores of two or more. Table 2 shows the yearly unadjusted costs according to different comorbid conditions, symptoms, and medications. The adjusted yearly cost per patient provides an estimate of the contribution of that disease, taking into account only age, gender and comorbidity. Diabetes (unadjusted) yields $5,174 in yearly costs, $3,240 above the mean of $1,934 for the whole population; however, when age, gender and comorbidity are taken into account, the adjusted yearly costs for diabetes is $3,419, only $1,485 above the mean. Thus, the unadjusted estimates for diabetes are inflated by the presence of other comorbid conditions.

The derivation model

To be included in the derivation model, the variables in Tables 1 and 2 had to explain more than 1% of the variance. When all were incorporated into the full derivation model, age, Medicare, Medicaid and self insurance remained predictive, with all but self insurance indicating increased costs. In addition to comorbidity score, four diseases, specifically, diabetes, hypertension, depression and skin ulcers/cellulitis were predictors of higher total costs ($P<.0001$). In addition, five medications, namely, the use of calcium channel or beta blockers, sedative/hypnotics, narcotic analgesics, and warfarin all predicted increased costs ($P<.0001$). The derivation model had an explained variance of 28.4%. The analysis using imputed variables for those patients with a missing age yielded identical results.

The validation model

Table 3 shows the average yearly costs adjusted for the variables that met the criteria for final entry into the multivariate model. Twelve variables that were significant in the validation model are included in Table 3. Older patients and those with Medicare or Medicaid had higher yearly costs. Patients with higher comorbidity had significantly higher costs, with steep increases in yearly costs shown in patients with comorbidity scores of two or more. Among individual comorbid diseases, patients with skin ulcers/cellulitis or diabetes had the highest adjusted yearly costs. Patients who were taking warfarin, narcotic analgesics or sedative/hypnotics also had significantly increased costs. The validation model explained 27.6% of the variance in the logarithm of total costs. The analysis using imputed variables for those patients with a missing age yielded identical results.

Figure 2 shows the relationship of total adjusted yearly costs according to comorbidity score and specific chronic illnesses. This emphasizes the reality that patients with specific disease alone do not experience dramatically greater costs; however, those with an index disease and higher comorbidity scores do have significantly higher costs.

Discussion

Since we did not use claims data, our study undoubtedly missed costs incurred outside New York Hospital. Our data also did not include expenditures related to prescription drugs or emergency room visits, which would be easily captured in a claims-based system. Hospitalization costs, the principal determinant of total costs, was likely underestimated in only 6% of patients. Although the lack of claims data makes our study less accurate in terms of total costs,[17] we believe that our physician-generated data allowed more accuracy in the measurement of clinical status, including cumulative comorbidity, a more or less crucial component.

Considering these caveats, our average yearly total cost per patient in 1994 was $1,934. This is consistent with data from other studies. In 1992, a large staff model HMO in Seattle showed a mean total cost estimate of $2,006.[18] Similar costs were obtained from a study of enrollees in Minnesota.[19] The cost of care at an academic institution such as ours may be higher than at other centers.[20 21] Moreover, medical services exhibit geographic variation,[22 23] and costs are higher in New York City.[24 25 26] The breakdown of total cost was as expected, with hospital costs accounting for nearly two thirds and ambulatory costs, one third of the total. In most studies, a small proportion of patients accounts for a large percentage of the cost. Thus, in a study of continuously enrolled Medicare beneficiaries over a four-year period, 18% percent accounted for 88% of cost, a characteristic which remained stable over time.[27] The issue is how to identify these patients prospectively; such identification would allow appropriate adjustment of rates, and interventions targeted to patients likely to sustain high costs.

Clinical variables have been shown in many studies to predict health care expenditures.[2 5 6 7 8 9 18 28 29 30 31 32 33] We also found that specific sub-populations of patients carrying specific diagnoses or on specific medications having incurred significantly higher total costs. Thus, controlling for age, insurance and comorbidity, patients with skin ulcers/cellulitis, diabetes, hypertension and depression had significantly higher costs than patients without those diseases, as did patients on warfarin, sedative/hypnotics and narcotic analgesics.

Surprisingly, while the contribution of specific chronic diseases or diagnostic groups to yearly costs of care has been explored, the role of comorbidity, the total burden of chronic diseases, has received little attention. In one study, the 38% of patients with two or more chronic conditions accounted for 71% of the total costs.[18] Comorbidity has been shown to be an important determinant of hospital cost: Swartz et al demonstrated that adding statistically significant comorbidity to a DRG-based model improved its ability to predict hospitalization cost by 19 percent.[11] The importance of capturing coexisting disease is also evident in the evolution of "coexisting condition" models.[8] However, most cost-prediction models are based on DRGs coded from hospital discharge data, and hence do not sufficiently capture the full longitudinal picture of comorbidity or reliably distinguish between comorbidity and complications.[11] Our study is the first to incorporate a prospectively obtained comorbidity index[10] in a rigorous statistical model aimed at predicting total cost of care.

Our model confirmed that older patients and those with Medicare or Medicaid incur higher total annual costs.[18 19 34] In both Medicare and Medicaid patients, comorbidity plays a critical role in explaining total costs. In our study, comorbidity explained 15.5% of the variance in costs and proved the most important predictor of cost. The 6.2 percent of patients with a comorbidity index of 3 or more incurred 22.3 percent of the total cost, whereas the 13.8 percent of patients with a comorbidity score of 2 or more incurred 39.6 percent of the cost. No specific comorbid disease predominated among those patients with high comorbidity scores, but rather, all diseases seemed to contribute to a more or less equivalent degree.

Medicare's adjusted average per capita cost model (AAPCC), which is based solely on sociodemographic characteristics, accounts for only 1 percent of variation in health care expenditures.[3] A recently developed PIP-DCG (Principal Inpatient Diagnostic Cost Groups) method explains 5.5%, whereas the all-diagnosis DCG method explains 8.6%.[3] Ellis et al[8] found that hierarchical coexisting condition models (HCC, HCCP and HCCPH) did somewhat better, but still only explained 9% of the variance in Medicare payments. In another analysis, Gruenberg et al[5] achieved an R^2 of 13.2% after incorporating prior-use in a broad, "comprehensive" disability model, which had already included health measures, and function. Even the best models explain only a small amount of the cost equation is probably because a significant portion of health care cost may be the result of random future events and thus impossible to predict.

It has been postulated that the maximum explainable variance in a prospective predictive model of this sort cannot substantially exceed a ceiling of 15 to 20 percent.[35 36 37] However, this result is based on the assumption that only stable-over-time patient characteristics are available for use as predictors. We believe our model, which includes comorbidity and therefore captures some time-varying patient characteristics is able to explain a higher maximum variance than previously suggested.

Despite its relatively high predictive ability, there still remain several areas in which our model is deficient, and whose inclusion would likely have improved its predictive power. In our study, we did not have data on patients' perceived health status,[6] functional status[19] or disabilities [5 28]which are significant predictors of cost. A potentially more important area that we did not address involves prior utilization, generally considered the most important predictor of health care cost. [36] Epstein and Cumella found prior utilization to be a strong predictor of total medical costs, explaining an average variance of 5.8%.[6] Gruenberg et al showed that adding prior use improved the best alternative cost-prediction model by 7.4%.[5] Anderson et al studied three prior utilization models - cost related groups, diagnostic cost groups and payment amount for capitated systems– and found all three to be superior to the AAPCC in predicting utilization.[2] Our model did not incorporate past utilization or prior cost.

Other important elements that, if included, might have improved our model's predictive power include certain socioeconomic characteristics (i.e., income, educational level) which have been reported to predict utilization in some instances.[6 38 39] Race may also be significant, as African-American patients have been shown to receive inadequate routine primary care, which in turn may increase their utilization of inpatient services.[39 40]

Unlike our total cost model, no diagnosis, disease entity or other related factor proved statistically significantly predictive of total hospitalization cost except for advancing age and increasing comorbidity score. Our inability to detect other predictors in this more confined cohort of hospitalized patients may be due to the small number of patients, which limited the model's power.

This has been a longitudinal study examining predictors of utilization and total cost of care of a large, diverse, general medicine population over a one-year period with data collected prospectively in the process of clinical practice. Having successfully identified a statistically significant and clinically important set of predictors of utilization and cost will allow us to explain and devise ways to control costs by targeting those patients where such predictors are manifest. We believe that the major contribution of our study lies in the inclusion of comorbidity as a major predictor of total cost in a rigorous predictive model.

Disease management is a systematic, population-based approach to patient care that aims to curb utilization by optimizing the process of care, increasing efficiency and managing the "total" disease.[41] [42] [43] After patients with diseases amenable to intervention are identified, specific programs of care across the entire health care delivery spectrum are implemented in order to improve outcomes, prevent unnecessary health care utilization and decrease expenditures. Currently, disease management programs have focused on chronic diseases such as diabetes, hypertension and congestive heart failure.

Whether disease management has had a favorable impact on outcomes or cost has been a matter of debate, although preliminary reports have been positive[44] when this approach has been used in a focused fashion. Without taking this approach for granted, we would venture to make a somewhat different case for the management not of specific diseases, but of comorbidity. Our study proves that, in addition to focusing solely on the traditionally recognized predictors of health care cost, we must recognize the extent of total comorbidity as a significant predictor. We have demonstrated that, by adding comorbidity as an explanatory variable, we can substantially improve the cost-predictive power of existing models and exceed the previous theoretical barrier of maximum allowable predictability. As a result, the more efficient management of any single chronic disease may not be sufficient in shifting the cost balance. Rather, it might be important to focus on patients with significant comorbidity.

Table 1 The relationship of age, gender, insurance, comorbidity and impaired mobility to average yearly cost per patient (N=15,186)

Demographic and clinical variables	Average Cost (± SE)	N	Percent of patients
Age*			
≤20	$1,284 ± 458	129	0.8%
20-29	$ 895 ± 99	2,209	14.5%
30-39	$1,143 ± 87	2,984	19.6%
40-49	$1,630 ± 129	2,591	17.1%
50-59	$2,251 ± 173	2,426	16.0%
60-69	$2,901 ± 207	2,128	14.0%
70-79	$2,960 ± 217	1,587	10.5%
80-89	$3,527 ± 346	735	4.8%
≥90	$3,596 ± 914	113	0.7%
Gender			
Female	$1,848 ± 66	10,408	68.5%
Male	$2,131 ± 121	4,751	31.3%
Insurance			
Medicaid*	$2,675 ± 142	4,022	26.5%
Medicare*	$3,414 ± 174	2,787	18.4%
Self*	$1,263 ± 106	4,030	26.5%
Employees	$ 948 ± 55	1,015	6.7%
Managed*	$859 ± 54	3,097	20.4%
Comorbidity*			
0	$1,147 ± 50	9,685	64.9%
1	$1,951 ± 93	3,406	22.4%
2	$4,422 ± 375	1,146	7.5%
≥3	$6,900 ± 527	949	6.3%
	$6,489 ± 1,493	568	0.7%

All were significant predictors of the logarithm of total costs at P<.0001.
*Explained more than 1% of the variance

Table 2 The relationship of chronic diseases, symptoms and medications to average yearly cost per patient

	Mean yearly Cost per patient unadjusted (± SE)	Yearly cost adjusted for age, gender and comorbidity (± SE)	Number of patients	Percent of patients
Chronic diseases				
Hypertension*	$3,070 ± 143	$2,156 ± 126	4,000	26.3%
Diabetes*	$5,174 ± 422	$3,419 ± 239	1,019	6.7%
Ulcer disease*	$3,367 ± 210	$1,685 ± 171	2,110	13.9%
Ischemic Heart Disease*	$4,912 ± 391	$3.206 ± 242	894	5.8%
Osteoarthritis*	$2,546 ± 178	$1,540 ± 164	2,122	13.9%
Cancer*	$4,565 ± 388	$1,085 ± 347	633	3.5%
Asthma*	$3,554 ± 293	$2,157 ± 195	1539	10.1%
Depression*	$2.931 ± 235	$2,326 ± 236	946	6.2%
COPD*	$3,301 ± 337	$1,253 ± 264	817	5.4%
Congestive heart failure*	$7,180 ± 713	$4,434 ± 372	425	2.8%
Arrhythmias*	$4,564 ± 575	$3,046 ± 345	455	3.0%
Skin ulcers/cellulitis*	$7,861 ± 1,372	$7,126 ± 523	191	1.3%
Renal disease*	$11,700 ± 2,790	$8,049 ± 687	116	0.8%
Peripheral vascular disease*	$4,556 ± 676	$1,633 ± 429	301	2.0%
Stroke*	$5,140 ± 842	$2,409 ± 469	251	1.7%
Endocarditis	$5,139 ± 771	$4,137 ± 431	284	1.9%
Rheumatoid arthritis	$3,553 ± 547	$2,110 ± 451	261	1.8%
Chronic liver disease	$3,188 ± 517	$822 ± 559	170	1.1%
Dementia	$4,586 ± 903	$2,477 ± 593	153	1.0%
Fracture	$3,735 ± 826	$3,262 ± 715	102	0.7%
Symptoms/syndromes				
Abdominal pain*	$2,717 ± 221	$1,943 ± 218	1,116	7.3%
Chest pain*	$2,332 ± 197	$1,498 ± 242	905	5.9%
Back pain*	$2,089 ± 164	$1,547 ± 203	1,277	8.4%
Functional GI	$2,653 ± 287	$1,264 ± 314	350	2.3%
Dizziness	$2,695 ± 317	$1,732 ± 333	476	3.1%
Fatigue	$2,221 ± 253	$1,886 ± 255	798	5.3%
Headache	$1,951 ± 172	$1,690 ± 274	694	4.6%
Medications				
Calcium channel blockers*	$3,177 ± 228	$2,086 ± 182	1,719	11.3%
Beta blockers*	$3,409 ± 271	$2,521 ± 243	918	6.0%
Sedative/hypnotics*	$4,289 ± 457	$3412 ± 241	906	6.0%
Narcotic analgesics*	$4,167 ± 455	$3,043 ± 274	695	4.6%
Warfarin*	$10,664 ± 1,812	$9,239 ± 521	192	1.3%
Oral steroids	$5,770 ± 1,392	$4,201 ± 561	166	1.1%
Anti-psychotics	$7,002 ± 2,040	$5,957 ± 654	122	0.8%

All are significant predictors of the logarithm of total yearly cost per patient at $P<.0001$.
*Explained more than 1% of the variance

Table 3 Multivariate model of average yearly costs as a function of predictors

Demographic and clinical variables	*Adjusted yearly total cost*
Age	
≤20	$2,452 ± 924
20-29	$1,771 ± 231
30-39	$1,831 ± 198
40-49	$1,723 ± 207
50-59	$2,221 ± 209
60-69	$1,973 ± 232
70-79	$1925 ± 305
80-89	$2,885 ± 424
≥90	$1,517 ± 1011
Insurance	
Medicare	$2,763 ± 273
Medicaid	$2,681 ± 186
Self	$2,232 ± 194
Comorbidity	
0	$1,594 ± 111
1	$1,581 ± 181
2	$3,406 ± 320
≥3	$5,118 ± 358
Chronic Diseases	
Skin ulcers/cellulitis	$8,296 ± 751
Diabetes	$3,034 ± 345
Hypertension	$2109 ± 180
Depression	$2,050 ± 340
Medications	
Narcotic analgesics	$2,577 ± 402
Sedative/hypnotics	$2,348 ± 348
Warfarin	$11,242 ± 789

All are significant predictors of the logarithm of total yearly cost per patient at P<.0001.

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Figure 1. Average Cost Per Patient Per Year According to Age and Comorbidity Score

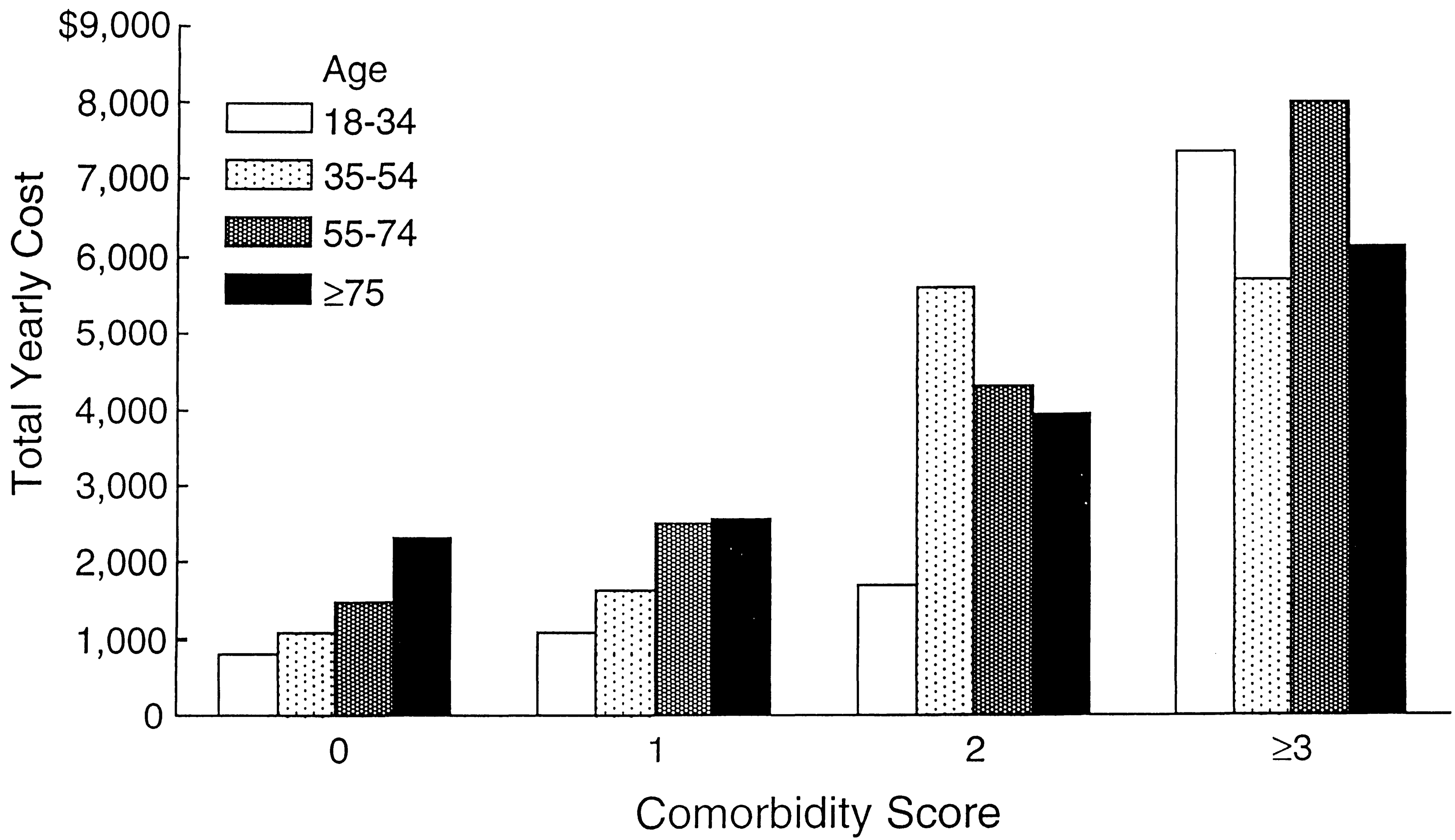

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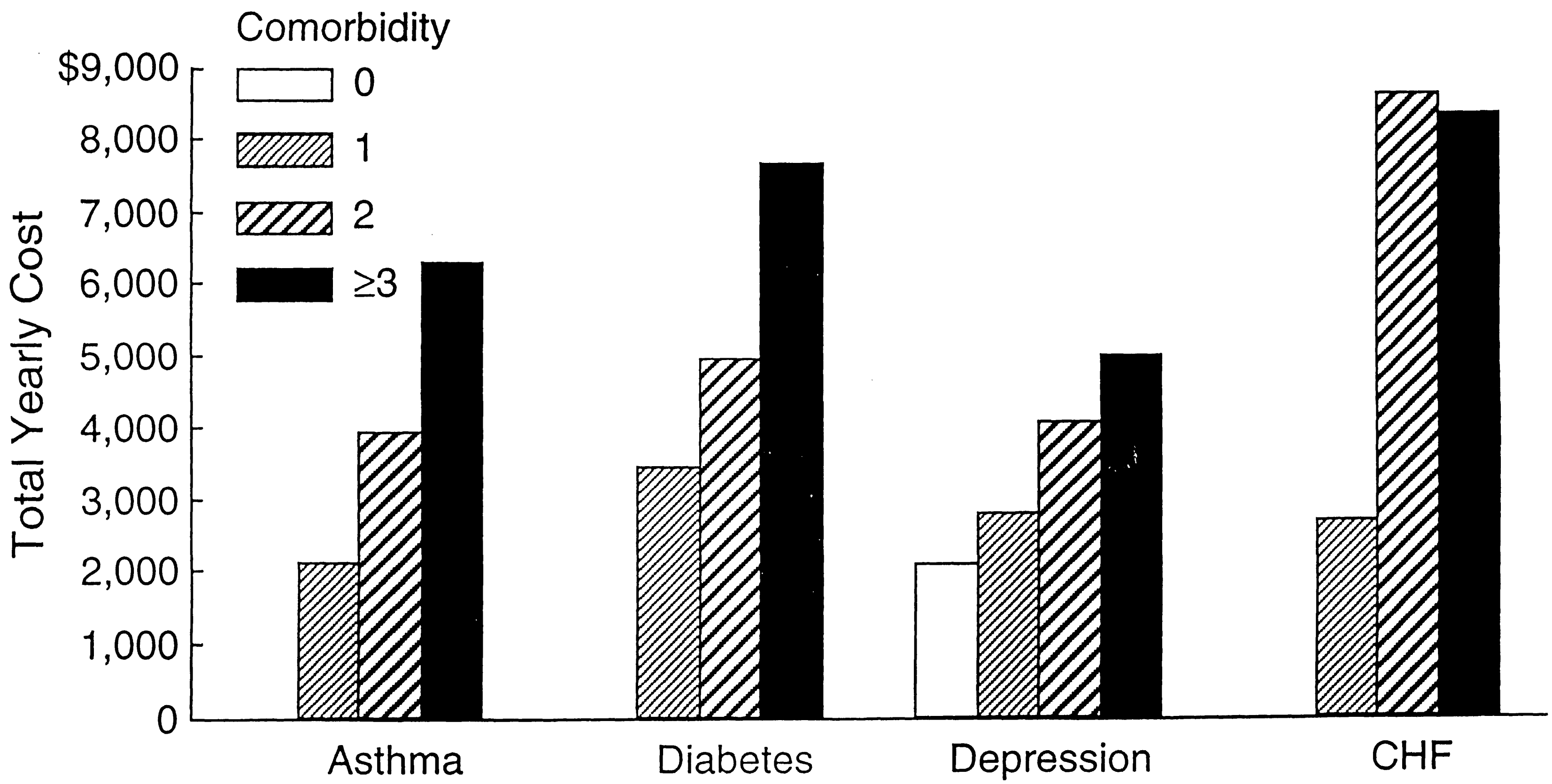
Figure 2. Total Costs Per Year According to Specific Diseases and Overall Comorbidity



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